Annales Universitatis Paedagogicae Cracoviensis
Studia Naturae, 3: 125–134, 2018, ISSN 2543-8832
DOI: 10.24917/25438832.3.9

Iwona Ałtyn, Magdalena Twarużek*

Department of Physiology and Toxicology, Institute of Experimental Biology, Faculty of Natural Sciences, Kazimierz Wielki University, Chodkiewicza 30 St., 85-064 Bydgoszcz, Poland,
*twarmag@ukw.edu.pl; https://orcid.org/0000-0002-8655-0067, https://orcid.org/0000-0002-2568-1178

Heavy metal and mould contamination of herbal medicinal products – an overview

The medicinal plant consists of many active chemicals, such as mucilage, polyphenols, polysaccharides, etc., which may modify the effects of the active principles. Therefore, it is believed that some natural remedies may have toxic effects on the body or act as an agonist or antagonist of the active substance (Dar, 2013). That is why toxicity tests for the pre-assessment of the efficacy of plant extracts are so important (Hewawasam, 2016). Herbal plants are exposed to different types of pollution, from chemical to microbiological, which, as mentioned above, can have a negative impact on the human body.

There are numerous causes of chemical and microbiological pollution. One of them may be associated with the usage of human excreta, animal manures, and sewage as fertilisers. The World Health Organization's (WHO) guidelines of Good Agricultural and Collection Practices (GACP) for medicinal plants prohibit the use of human manure as fertiliser. Moreover, they insist that animal manure should be thoroughly composted (*WHO*, 2003). Another cause of chemical pollution may be found in composted sewage, as well as in chemicals used in households and industrial chemicals, as the vast majority of them are found in analysed herbs and herbal materials. The listed potential sources of herbal contamination may lead to the appearance of unwanted chemicals, not just during the preparation process, but also in its final product. According to the World Health Organization's research, the level of pollution present in medicinal plants may change in different stages of its manufacture, such as post-harvest processing (e.g., drying), herbal preparation – extraction process, as well as in the finished herbal products (*WHO*, 2007). Therefore, the manufacture process of herbal preparation or its final pharmaceutical product should be controlled at each stage of production by GACP for medical plants and by Good Manufacturing Practices (GMP) for herbal medicines.

The purpose of this review is to show the mycological and chemical contamination of medicinal plants, as well as to indicate several important challenges related to the effective monitornig of their safety.

Contamination by heavy metals

The rapid growth of industry and agriculture in recent times has caused a serious problem of contamination of air, soil, and water with heavy metals (Orisakwe et al., 2012). Heavy metals are generally defined as a collection of metalloids with anatomic density greater than 6 g/cm^3. Moreover, some of them (cadmium Cd, chromium Cr, copper Cu, mercury Hg, nickel Ni, lead Pb and zinc Zn) possess toxic properties (Awodele et al., 2013). In the sciences of biology and medicine, heavy metals are defined as elements used in the industry and simultaneously characterised by the toxicity to humans or the environment. The widespread environmental dispersion of heavy metals enter into the food chains through the epidemic pollution of air, water, and soil during cultivation (Husain et al., 1995).

The use of herbal plant contaminated by heavy metals for the production of herbal medicines can trigger chronic accumulation of metals in the human organs (Ajasa et al., 2004; Ang et al., 2006; Arzani et al., 2007). Bioaccumulation of heavy metals in the body can cause both short-term and long-term health damages. It can cause abdominal pain, disease of the foetus, which may lead to abortion and/or preterm labour, as well as mental retardation to children, while adults may suffer from hypertension, fatigue, as well as impaired kidney and brain damage (Hifsa et al., 2009). Prolonged consumption of products contaminated with heavy metals may also lead to skin eruptions, intestinal ulcers, and different types of cancer (Shad et al., 2008). Due to the high health risks, the WHO has developed limit guidelines for the maximum values of these compounds in herbal medicine. According to the WHO, remedies should be checked for the presence of different contaminants such as heavy/toxic metals, fungi, and microorganisms (*WHO*, 1998; 2007).

Several studies have tested herbal medicine preparations for heavy metal contamination. Filipiak-Szok et al. (2015) determined the highest concentration of lead Pb (9.27 μg), cadmium Cd (0.36 μg) and arsenic As (1.25 μg/g), in dietary supplements. For Ni 0.16–14.21 μg/g dry mass (d.m.), while for Ba 0.49–11.45 μg/tablet and 11.64 μg/g d.m. The lowest concentration of all analysed heavy metals was found for antimony Sb. For plants it was at the level of 0.003 μg/g d.m. and 0.10 μg/g d.m. for dietary supplements. Chuang et al. (2000) and Singh and Garg (1997), analysed the Chinese root of *Panax ginseng* C.A. Meyer. The results showed the level of Pb as – 0.16 ± 0.11 μg/g, Cd as – 0.06 ± 0.04 μg/g and As as – 0.05 ± 0.03 μg/g; 4.62μg/g barium Ba and 223 μg/g Sb.

Olowoyo et al. (2012) showed that the maximum concentration of zinc Zn in the roots of *Datura stramonium* L. was recorded at value of 90.65 ± 1.22 µg/g. The concentration of Cu from both plant parts ranged from 3.84 ± 0.33 µg/g – 14.05 ± 0.02 µg/g. Contamination by nickel Ni from the plant parts were in the range from 4.36 ± 0.25 µg/g to 15.78 ± 0.14 µg/g. Pb concentration in all the plant parts ranged from 0.51 ± 0.01 µg/g to 2.13 ± 0.02 µg/g, while Cr levels ranged from 5.65 ± 0.05 µg/g to 18.31 ± 0.01 µg/g.

Başgel et al. (2006) determined the high concentration of calcium Ca from 965 mg/kg (*Rosae caninae fructus*) to 17.740 mg/kg (*Tilia* × *vulgaris* H. and *Urtica dioica* L.). Magnesium Mg in the seven herbs and their infusions was in the range of 1643–3778 mg/kg and 610–2078 mg/kg, respectively. The iron Fe content of the herbs and their infusions was in the range of 224–502.7 mg/kg and 4.90–107.4 mg/kg, respectively. The content of Al in the herbs varied between 87 mg/kg (*T.* × *vulgaris*) and 596 mg/kg (*U. dioica*). Manganese Mn in the herbs varied in a wide range of 23–244 mg/kg (*R. c. fructus*); whereas, its concentration in the infusions varied between 4.30 mg/kg (*Foeniculum vulgare* Mill.) and 49.1 mg/kg (*R. c. fructus*). The highest concentration of Cu was in the *Matricaria chammomilla* L. infusion as 6.75 mg/kg and the lowest value was determined in the *Cassia anqustifolia* Vahl infusion as 2.45 mg/kg. Sr in the herbs was found between the range of 17.5 mg/kg (*Salvia officinalis* L.) and 174 mg/kg (*U. dioica*); whereas, in the infusions, it varied between 2.45 mg/kg (*S. officinalis*) and 43 mg/kg (*U. dioica*).

Caldas (2004) showed that none of the 38 analysed samples of *Cynara cardunculus* var. *scolymus* (L.) Fiori, *Solanum melongena* L. or *Paullinia cupana* Kunth contained detectable levels of cadmium Cd (< 0.2 mg/g), mercury Hg (< 0.01 mg/g), or lead Pb (< 2.0 mg/g). Cadmium concentrations varied from < 0.20 to 0.74 mg/g. *Centella asiatica* (L.) Urban. The levels of Hg varied from < 0.01 to 0.09 mg/g with *Ginkgo biloba* L. The levels of lead in the samples varied from < 2.0 to 1480 mg/g with *Aesculus hippocastanum* L. having the highest concentrations.

Ting et al. (2013) research on Chinese herbal medicine showed that out of the 6 metals (Mn, Pb, Cu, Cd, Fe, Zn), the highest concentration which reached the level of 1.394–18.545 mg/L belonged to Mn. Cd had the lowest level which was identified as 0.105–0.314 mg/L. Other metals were all < 3 mg/L. Naga Raju et al. (2006) showed that *Ocimum sanctum* L. were contaminated by Ni (24.1 ± 4.7 µg/g). The same high level of Ni 33.7 ± 50 µg/g was shown in the results of a study conducted by Gowrishankar et al. (2010). The *O. sanctum* was an object of research conducted by Professor Kumar and his team. In their work, the results showed very high concentration of Al at the 8249 µg/g (Devi et al., 2008). Harris et al. (2011) study showed that all samples of Chinese herbal medicine were contained by at least one heavy metal. 34.4% of samples had detectable levels of all five metals. The highest concentration of Cr and Ar, were

21 ppm and 20 ppm, respectively (Egan et al., 2007; Lendinez et al., 2001; Saper et al., 2004; *USDA*, 2009; *US FDA*, 2007; *US GAO*, 2010).

Fungal contamination

Moulds comprise a large group of around 100 thousand species, and they are widely distributed in nature. Moreover, they are one of the most widespread environmental pollutants. The reason for this phenomenon is connected with their high ability to multiply on various raw materials, under favourable conditions (Ahmad et al., 2014). Therefore, it is estimated that approx. 25% of them have moulds (Hussein et al., 2001). Contamination by such fungi as *Aspergillus* spp., *Penicillium* spp., *Fusarium* spp. and *Alternaria* spp. is especially dangerous due to the production of toxic secondary metabolites – mycotoxins, which can cause both acute and chronic toxicities or even death (*FAO*, 2001).

Herbal medicinal products preparations have been analysed for fungal contamination in a number of studies. Efuntoye (1996) showed that samples were contaminated by the colony of *Aspergillus* spp., *Pencillium* spp., *Fusarium* spp., and *Rhizopus* spp. Moreover, *Mucor* spp., *Aspergillus* spp. was isolated in all the samples of studied herbs, while the species *Aspergillus niger* Tiegh and *A. flavus* Link were the most prevalent. The genus *Fusarium* spp. was found in six of the plants studies. Colonies of *Trichoderma viride* Pers. were isolated from *Azadirachta indica* A. Juss., *Plumbago zeylanica* L. and *Jatropha curcas* L., while colonies of *Cladosporium bantianum* (Sacc.) Borelli and *Alternaria humieola* Oudem. were found in *Xylopia aethiopica* (Dunal) A.Rich. and *Mangifera indica* L., respectively. *Penicillium* spp. were found in samples, with frequency at a level of 87.5% and makes up 18.5% of the total fungi.

Tournas et al. (2006) showed that 100% of the Siberian, 56% of the Chinese and 48% of the American ginseng root samples were contaminated with fungi. The highest contamination level (4.3×10^5 cfu/g) was observed in the locally grown American ginseng root, while the lowest (< 100 cfu/g) in ginseng extract. *Alternaria alternata* (Fr.) Keissl. was found at levels as high as 4.0×10^4 cfu/g, while *Aspergillus* spp. and *Cladosporium* spp. were found at levels ranging between < 100 and 1.0×10^4 cfu/g. *Eurotium chevalieri* L. was present in 11%, whereas *Penicillium* spp., *Rhizopus* spp. and yeasts were found in 33% of the tested samples. *Penicillium* spp. levels were between < 100 and 1.0×10^3 cfu/g. The lowest level (< 100 – 4.0×10^2 cfu/g) of *Aspergillus niger* was present in 22% of the samples. Additionally, Raman et al. (2004) also examined the dietary supplements including ginseng and the results showed that samples were contaminated with fungi, but the study did not quantify the fungal contaminants. Zhang and Zhang (2002) also isolated moulds from American ginseng seeds. According to the results of their work, researched samples were contaminated by high levels of *Fusarium* spp., *Alternaria* spp., *Penicillium* spp., *Rhizopus* spp. and low levels of *Aspergillus* spp.

Rajeshwari and Raveesha (2016) revealed that 6 of the herbal drugs' raw materials were highly contaminated: *Withania somnifera* (L.) Dunal (100%) followed by *Curcuma angustifolia* Roxb. (92%), *Centella asiatica* (L.) Urban (88.6%), *Acorus calamus* L. (88%), *Tinospora cordifloia* (Willd.) Hook. f. & Thomson (86%), and *Myristica fragrans* Houtt. (82%). Therefore, researchers were able to identify and isolate 41 fungal species belonging to 16 genera. The most predominant were *Aspergillus* spp. and *Penicillum* spp., while the *A. niger* was the most frequently occurring fungi. Roy and Chourasia (1990) analysed traditional herbal drugs from India. The results showed that *Aspergillus* spp., *Fusarium* spp., *Penicillium* spp. and *Trichoderma* spp. were the common moulds isolated from most of the samples. *Aspergillus* spp. were isolated from almost all samples with a frequency at 66.2% on *Strychnos nux-vomica* L. seeds. The *Fusarium* spp. was at the level of 11.6 ± 6.5 in the 3 samples of *Ichnocarpus frutescens* (L.) W.T.Aiton.

Hitokoto et al. (1978), while analysing herbal drugs' samples, discovered that the most predominant fungi were *Aspergillus* spp. and *Penicillium* spp. *Mucor* spp., *Rhizopus* spp., *Cladosporium* spp., and *Aureobasidium* spp. were found in a few samples. The species of *Penicillium* spp. predominated from powdered Japanese peony roots – *Paeoniae Radix Pulverata* (2.579 colonies/g) and powdered coptis – *Coptidis Rhizoma Pulveratum* (9.500 colonies/g). *Aspergillus* spp. with the highest frequency was found in powdered coptis (3.438/g), powdered scutellaria roots – *Scutellariae Radix Pulverata* (2.241/g), powdered Japanese peony roots (1.523/g), and powdered cininidium – *Cinidii Rhizoma Pulveratum* (1.133/g). The species *A. niger* was the most frequently encountered group in the drugs, accounting for 24.6% of the total isolates. The *Aspergillus glaucus* (L.) Link and *A. flavus* Link were the next most prevalent species with 9.3% and 7.8% of the total isolates, respectively. On the other hand, Udagawa et al. (1976) showed that *A. niger*, *A. glaucus* and *A. flavus* were the most prevalent species in herbal drugs.

Matsushima et al. (1958) showed that *Aspergillus awamori* Nakaz., *A. glaucus*, *A. mangini* Thom & Raper, *A. niger*, *A. ochraceus* Wihelm, *Penicillium frequentans* West., *P. variabile* Sopp., O.J., and *Rhizopus* spp. were predominant. Chourasia (1995) examined the herbal drugs from the Indian Pharmacopoeia. The maximum level of fungi was found in the fruits of *Piper longum* L., *P. nigrum* L. and *Elettaria cardamomum* (L.) Maton. The most frequently isolated fungi were *Aspergillus* spp. and *Fusarium* spp., while the lowest frequently isolated ones were *Alternaria* spp., *Emericella* spp., *Mucor* spp., *Penicillium* spp., and *Chaetomium* spp.

Rizzo et al. (2004) conducted a study to assess the presence of fungi in dried medicinal herbs. 27% of all samples were contaminated with *Aspergillus flavi* section, 25% *Circumdati* section (*Aspergillus alliaceus* Thom & Church, *A. ochraceus and A. sclerotiorum* G.A. Huber) and 16% with *Fusarium* spp. The most frequent contaminants were *A. nigri*.

Ahmad et al. (2014) studies showed that 90% of medicinal plant samples were contaminated with moulds and 70% of them exceeded the permissible limits determined by the *United States Pharmacopeia* (2005). Mould contamination in *Withania coagulans* (Stocks) Dunal (3.4×10^{11} CFU g^{-1}), *Papaver somniferum* L. (6.1×10^{12} CFU g^{-1}), *Olea europaea* L. (1.08×105 CFU g^{-1}), *Stevia rebaudiana* (Bertoni) Bertoni (7.1×10^{5} CFU g^{-1}), *Ocimum basilicum* L. (2.4×10^{5} CFU g^{-1}), *Aloe vera* (L.) Burm. f. (3.5×10^{3} CFU g^{-1}), *Opuntia monacantha* Haw. (5.8×10^{4}), *Glycyrrhiza gabra* L. (2.2×10^{5} CFU g^{-1}), and *Cymbopogon citratus* (DC.) Stapf (4.6×10^{3} CFU g^{-1}) were observed less often but still in a significant quantity. The most frequently isolated species were *Aspergillus niger*, *A. flavus*, *A. parasiticus*, Speare, *A. terreus* Thorn, *Penicillium verrucosum* Dierckx, *P. citrinum* Thom. C, *Fusarium* sp., *Rhizopus* sp., and *Alternaria alternata*. Among them, *Aspergillus niger* were found in 50% of the samples, followed by *A. flavus* reaching 43%. Those results are in agreement with findings of Abou-Arab et al. (1999) and Abou Donia (2008), which showed that *A. niger* and *A. flavus* were the most dominant moulds in the collected samples of medicinal herbs in Egypt.

Bugno et al. (2006) results showed that, in *Cymbopogon citratus* (DC. ex Nees) Stapf, the level of fungal pollution was of 3.98×10^{5} cfu/g^{-1}. Additionally, research conducted by Jahani et al. (2013) on the subject of fungal contamination in barberry showed high levels of *Aspergillus* spp. and *Penicillium* spp. Filipiak-Szok et al. (2016) examination of plants and dietary supplements showed that the sum of moulds and yeast were lower than 69 cfu/g^{-1}, with the most frequently species *Cladosporium* spp. Rawat et al. (2014) examined 40 samples of 8 different medicinal plants: *Saraca indica* L., *Terminalia arjuna* (Roxb.) Wight & Arn., *Withania somnifera* (L.) Dunal, *Bacopa monnieri* (L.) Wettst., *Evolvulus alsinoides* (Linn.) Linn., *Zingiber officinale* Roscoe. 92.5% of all analysed samples were found to be contaminated by more than one fungal species. Those findings revealed that the highest frequency of contamination in samples belongs to *Aspergillus niger* (38.56%) then *Mucor* spp. (32.05%), *Rihzopus* spp. (12.82%), *A. flavus* (12.82%), *A. nidulans* (2.56%) and *Myceliophthora* spp. (1.28%).

Conclusions

Nowadays, due to the stressful working mode and lack of time for healthy meals, consumers are increasingly relying on medicinal plants as medications for health and ailments, or even dietary supplements. The presented results of multiple research studies indicate that plants for medical use should be carefully stored and evaluated for their possible contamination. Long-term studies on heavy metal and fungal contaminants show how important monitoring is in determining the safe levels of pollutant concentration in medicinal plants and their products. Each level of contamination that humans are exposed to by the intake of medicinal plants needs to be considered individually for every type of medicinal plant. Therefore, to protect consumers against the contaminant health hazards, storage conditions of medicinal plants should be improved. Moreover, good agricultural practice should be implemented to lower the presence of moulds on the medicinal plants. Due to the wide range of different factors threatening a plant's health, it is very important to continuously exert regular mycological evaluations. The presented research results not only allow one to determine the degree of potential threat but also, what is even more important, to raise the awareness about the importance of improvement in the processing techniques, i.e. harvesting, drying, transport, and storage. Therefore, it can be stated that medicinal herb products for human consumption should be monitored for contaminants regardless of whether they are cultivated or collected from the wild.

References

Abou-Arab, A.A.K., Kawther, M.S., El Tantawy, M.E., Badeaa, R.I., Khayria, N. (1999). Quantity estimation of some contaminants in commonly used medicinal plants in the Egyptian market. *Food Chemistry*, 67*(4)*, 357–363. DOI: 10.1016/S0308-8146(99)00082-5

Abou Donia, M.A. (2008). Microbiological quality and aflatoxinogenesis of Egyptian spices and medicinal plants. *Global Veterinaria*, *2(4)*, 175–181. DOI: 10.1016/j.ram.2017.02.006

Ahmad, B., Ashiq, S., Hussain, A., Bashir, S., Hussain, M. (2014). Evaluation of mycotoxins, mycobiota, and toxigenic fungi in selected medicinal plants of Khyber Pakhtunkhwa, Pakistan. *Fungal Biology*, *118(9–10)*, 776–84. DOI: 10.1016/j.funbio.2014.06.002

Ajasa, A.M., Bello, M.O., Ibrahim, A.O., Ogunwande, I.A., Olawore, N.O. (2004). Heavy trace metals and macronutrients status in herbal plants of Nigeria. *Food Chemistry*, *85(1)*, 67–71. DOI: 10.1016/j.foodchem.2003.06.004

Ang, H.H., Lee, K.L. (2006). Contamination of Merkury in tongkat Ali hitam herbal preparations. *Food and Chemical Toxicology*, *44(8)*, 1245–1250. DOI: 10.1016/j.fct.2006.01.014

Arzani, A., Zeinali, H., Razmjo, K. (2007). Iron and magnesium concentrations of mint accessions (*Mentha* spp.). *Plant Physiology and Biochemistry*, *45(5)*, 323–329. DOI: 10.1016/j.plaphy.2007.03.023

Awodele, O., Popoola, T.D., Amadi, K.C., Coker, H.A., Akintonwa A. (2013). Traditional medicinal plants in Nigeria – remedies or risks. *Journal of Ethnopharmacology*, *150(2)*, 614–618. DOI: 10.1016/j.jep.2013.09.015

Başgel, S., Erdemoğlu, S.B. (2006). Determination of mineral and trace elements in some medicinal herbs and their infusions consumed in Turkey. *Science of the Total Environment*, *359(1–3)*, 82–9. DOI: 10.1016/j.scitotenv.2005.04.016

Bugno, A., Almodovar, A.B., Pereira, T.C., Pinto, T.J.A., Sabino, M. (2006). Occurrence of toxigenic fungi in herbal drugs. *Brazilian Journal of Microbiology*, *37*, 47–51. DOI: 10.1590/S1517-83822006000100009

Caldas, E.D., Machado, L.L. (2004). Cadmium, mercury and lead in medicinal herbs in Brazil. *Food and Chemical Toxicology*, *42(4)*, 599–603. DOI: 10.1016/j.fct.2003.11.004

Chaurasia, H.K. (1995). Mycobiota and mycotoxins in herbal drugs of Indian pharmaceutical industries. *Mycological Research*, *99(6)*, 697–703. DOI: 10.1016/S0953-7562(09)80531-5

Chuang, I.C., Chen, K.S., Huang, Y.L., Lee, P.N., Lin, T.H. (2000). Determination of trace elements in some natural drugs by atomic absorption spectrometry. *Biological Trace Element Research*, *76*, 235–44. DOI: 10.1385/BTER:76:3:235

Dar, A.S., Ganai, F.A., Yousuf, A.R., Balkhi, M.H., Bhat, T.M., Sharma, P. (2013). Pharmacological and toxicological evaluation of *Urtica dioca*. *Pharmaceutical Biology*, *51(2)*, 170–180. DOI: 10.3109/13880209.2012.715172

Devi, K.N., Sarma, H.N., Kumar, S. (2008). Estimation of essential and trace elements in some medicinal plants by PIXE and PIGE techniques. *Nuclear Instruments and Methods Physics Research Section B*, *266(8)*, 1605–1610. DOI: 10.1016/j.nimb.2007.12.004

Efuntoye, M.O. (1996). Fungi associated with herbal drug plants during storage. *Mycopathologia*, *136(2)*, 115–118.

Egan, S.K., Bolger, P.M., Carrington, C.D. (2007). Update of US FDA's Total diet study food list and diets. *Journal of Exposure Science and Environmental Epidemiology*, *17(6)*, 573–82. DOI: 10.1038/sj.jes.7500554

FAO (Food and Agriculture Organization of United Nations) (2001). Manual on the application of the HACCP system in mycotoxin prevention and control 73, Rome: FAO Food and Nutrition.

Filipiak-Szok, A., Kurzawa, M., Szłyk, E. (2015). Determination of toxic metals by ICP-MS in Asiatic and European medicinal plants and dietary supplements. *Journal of Trace Elements in Medicine and Biology*, *30*, 54–58. DOI: 10.1016/j.jtemb.2014.10.008

Filipiak-Szok, A., Kurzawa, M., Szłyk, E., Twarużek, M., Błajet-Kosicka, A., Grajewski, J. (2016). Determination of mycotoxins, alkaloids, phytochemicals, antioxidants and cytotoxicity in Asiatic Ginseng (Ashwagandha, Dong quai, *Panax ginseng*). *Chemical Papers*, *71(6)*, 1073–1082. DOI: 10.1007/s11696-016-0028-0

Gowrishankar, R., Kumar, M., Menon, V., Divi, S.M., Saravanan, M., Magudapathy, P., Panigrahi, B.K., Nair, K.G, Venkataramaniah, K. (2010). Trace element studies on *Tinospora cordifolia* (Menispermaceae), *Ocimum sanctum* (Lamiaceae), *Moringa oleifera* (Moringaceae), and *Phyllanthus niruri* (Euphorbiaceae) using PIXE. *Biological Trace Element Research*, *133(3)*, 357–363. DOI: 10.1007/s12011-009-8439-1

Harris, E.S.J., Cao, S., Littlefield, B.A., Craycroft, J.A., Scholten, R., Kaptchuk, T., Fu, Y., Wang, W., Liu, Y., Chen, H., Zhao, Z., Clardy, J., Woolf, A.D., Eisenberg, D.M. (2011). Heavy metal and pesticide content in commonly prescribed individual raw Chinese Herbal Medicines. *Science Total of Environment*, *409(20)*, 4297–4305. DOI: 10.1016/j.scitotenv.2011.07.032

Hewawasam, R.P., Jayatilaka, K.A.P.W., Mudduwaand, L.K.B., Pathirana, C. (2016). Toxicological evaluation of five Sri Lankan medicinal plants: a biochemical, haematological and histopathological assessment. *International Journal of Pharmaceutical Sciences and Research*, *7(10)*, 4014–4021. DOI: 10.13040/IJPSR.0975-8232.7(10).4014-21

Hifsa, M., Naeem, I., Taskeen, A., Zeb, S. (2009). Investigation of heavy metals in commercial spices brands. *New York Science Journal*, *2(5)*, 1554–2200.

Hitokoto, H., Morozumi, S., Wauke, T., Sakai, S., Kurata, H. (1978). Fungal contamination and mycotoxin detection of powdered herbal drugs. *Applied and Environmental Microbiology*, *36*, 252–256.

Husain, A., Baroon, Z., Al-Khalafawi, S., Al.-Ati, T., Sawaya, W. (1995). Heavy metals in fruits and vegetables grown in Kuwait Turing the oil well fires. *Arab Gulf Journal of science and Research*, *13(3)*, 535–542.

Hussein, H.S., Brasel, J.M. (2001). Toxicity, metabolism, and impact of mycotoxins on humans and animals. *Toxicology*, *167*, 101–134. DOI: 10.1016/S0300-483X(01)00471-1

Jahani, M., Rezaei, O.M., Khodadadi, M., Alemzadeh, E. (2013). A survey of fungal contamination associated with barberry (*Berberis* spp.) in Iran. *American Journal of Plant Sciences*, 4, 1594–1596. DOI: 10.4236/ajps.2013.48192

Lendinez, E., Lorenzo, M.L., Cabrera, C., Lopez, M.C. (2001). Chromium in basic foods of the Spanish diet: seafood, cereals, vegetables, olive oils and dairy products. *Science Total of Environment*, *278*, 183–189. DOI: 10.1016/S0048-9697(01)00647-7

Matsushima, T., Itoh, H., Ikeda, M. (1958). Investigation of the fungal spoilage of crude drugs. *Journal of Japanese Botany*, *33*, 12–23.

Naga Raju, G.J., Sarita, P., Ramana Murty, G.A.V., Ravi Kumar, M., Seetharami, B., Charles, J., Lakshminarayana, S., Seshi Reddy, T., Bhuloka Reddy, S., Vijanyan, V. (2006). Estimation of trace elements in some anti-diabetic medicinal plants using PIXE technique. *Applied Radiationand Isotopes*, *64*, 893–900. DOI: 10.1016/j.apradiso.2006.02.085

Olowoyo, J.O., Okedeyi, O.O., Mkolo, N.M., Lion, G.N., Mdakane, S.T.R. (2012). Uptake and translocation of heavy metals by medicinal plants growing around a waste dump site in Pretoria, South Africa. *South African Journal of Botany*, *78*, 116–121. DOI: 10.1016/j.sajb.2011.05.010

Orisakwe, O.S., Nduka, J.K., Amadi, C.N., Dike, D.O., Bede, O. (2012). Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern Nigeria. *Chemistry Central Journal*, *6*, 77. DOI: 10.1186/1752-153X-6-77

Rajeshwaria, P., Raveesha, KA. (2016). Mycological analysis and aflatoxin B_1 contaminant estimation of herbal drug raw materials. *African Journal of Traditional Complementary and Alternative Medicines*, *13(5)*, 123–131.

Raman, P., Patino, L.C., Nair, N.G. (2004). Evaluation of metal and microbial contamination. *Journal of Agricultural and Food Chemistry*, *52(26)*, 7822–7827. DOI: 10.1021/jf049150+

Rawat, A., Mahajan, S., Gupta, A., Agnihotri, R.K., Wahi, N., Sharma, R. (2014). Detection of toxigenic fungi and mycotoxins in some stored medicinal plant samples. *International Journal of Applied Sciences and Biotechnology*, *2(2)*, 211–216. DOI: 10.3126/ijasbt.v2i2.10457

Rizzo, I., Vedoya, G., Maurutto, S., Haidukowski, M., Varsavsky, E. (2004). Assessment of toxigenic fungi on Argentine and medicinal herbs. *Microbiological Research*, *159*, 113–120. DOI: 10.1016/j.micres.2004.01.013

Roy, A.K., Chourasia, H.K.J. (1990). Mycoflora, mycotoxin producibility and mycotoxins in traditional herbal drugs from India. *Journal of General and Applied Microbiology*, *36*, 295–302. DOI: 10.2323/jgam.36.295

Saper, R.B., Kales, S.N., Paquin, J., Burns, M.J., Eisenberg, D.M., Davis, R.B., Phillips, R.S. (2004). Heavy metal content of ayurvedic herbal medicine products. *Journal of the American Medical Association*, *292*, 2868–2873. DOI: 10.1001/jama.292.23.2868

Shad, A.K., Lajbar, K., Iqbal, H., Khan, B.M., Naveed, A. (2008). Profile heavy metals in selected medicinal plants. *Pakistan Journal of Weed Science Research*, *14(1–2)*, 101–110. DOI: 10.5829/idosi.gjp.2012.6.3.65128

Singh, V., Garg, A.N. (1997). Availability of essential trace elements in Ayurvedic Indian medicinal herbs using instrumental neutron activation analysis. *Applied Radiation and Isotopes*, *48(1)*, 97–101. DOI: 10.1016/S0969-8043(96)00043-7

Ting, A., Chow, Y., Tan, W. (2013). Microbial and heavy metal contamination in commonly consumer traditional Chinese herbal medicines. *Journal of Traditional Chinese Medicine*, *33(1)*, 119–124. DOI: 10.1016/S0254-6272(13)60112-0

Tournas, V.H., Katsoudas, E., Miracco, E.J. (2006). Moulds, yeasts and aerobic plate counts in ginseng supplements. *International Journal of Food Microbiology*, *108(2)*, 178–81. DOI: 10.1016/j.ijfoodmicro.2005.11.009

Udagawa, S., Kurata, H., Norizuki, K., Takatori, K., Nakao, M., Takahashi, K. (1976). Distribution of aflatoxin-producing fungi in crude drugs of plant origin. *Proceedings of the Japanese Association of Mycotoxicology*, *3/4*, 35–37.

United States Pharmacopeia 28 National Formulary 23 (USP 28/NF 23) (2005). *United States Pharmacopeial Convention Inc. Rockville, MD.*

USDA (United States Department of Agriculture) (2009). *Pesticide Date Program: annual summary, calendar year 2008. Washington, DC, United States: Agricultural Marketing Service, Science and Technology Programs.*

US FDA (United States Food and Drug Administration) (2007). *Total Diet Study Results. Revision 4.1, market baskets 1991 through 2005.* College Park, United States: US FDA, Centre for Food Safety and Applied Nutrition; 2007. [Internet] US FDA (United States Food and Drug Administration). Pesticide residues in food and feed – enforcement criteria (CPG Sec. 575.100).

UUS GAO (United States Government Accountability Office) (2010). *Herbal dietary supplements: examples of deceptive or questionable marketing practices and potentially dangerous advice*. Washington, DC, United States: US GAO.

WHO (World Health Organization) (1998). Quality Control Methods for Medicinal Plant Materials. WHO Press, Geneva, Switzerland.

WHO (World Health Organization) (2003). *WHO guidelines on good agricultural and field collection practices (GACP) for medicinal plants*. Geneva, World Health Organization.

WHO (World Health Organization) (2007). *WHO guidelines for assessing quality of herbal medicines with reference to contaminants and residues*. WHO 11.

Zhang, G.Z., Zhang, S.F. (2002). Fungal detection of American ginseng seeds from Beijing and northeast area in China. *Zhongguo Zhongyao Zazhi*, *27(9)*, 658–661.

Przegląd zanieczyszczeń metalami ciężkimi i pleśniami roślin leczniczych

Streszczenie

Rośliny zielarskie są powszechnie wykorzystywane jako surowce w przemyśle farmaceutycznym. Od czasów starożytnych ziół używa się w leczeniu i zapobieganiu chorób. Jednakże w dzisiejszych czasach mogą one nie spełniać wymagań dotyczących jakości, bezpieczeństwa i skuteczności. Większość produktów ziołowych nie jest testowana, a ich efekty działania są słabo monitorowane. Konsekwencją tego jest niewystarczająca wiedza na temat przebiegu ich działania, skutków ubocznych, przeciwwskazań oraz interakcji z występującymi na rynku produktami farmaceutycznymi oraz żywnością. Przyczyną negatywnego wpływu surowców ziołowych na organizm może być ich zanieczyszczenie przez różne grzyby pleśniowe, powstające podczas zbioru, przetwarzania, przechowywania, a także dystrybucji. Zanieczyszczenie surowców zielarskich może być również spowodowane przez różnorodne metale ciężkie, które występują w wielu aspektach współczesnego życia. Celem niniejszej pracy jest przegląd informacji na temat stanu mykologicznego i chemicznego roślin leczniczych, a także wskazanie kilku ważnych wyzwań związanych z efektywnym monitorowaniem ich bezpieczeństwa.

Key words: contamination, heavy metals, medicinal plants, mould

Received: [2018.02.23]

Accepted: [2018.10.16]